are contiguous, and the anterior eyes of the four intermediate ones forming the trapezoid, which are near to each other, are the smallest and darkest of the eight. The legs are provided with hairs, and have a yellowish brown hue; the anterior and posterior pairs, which are the longest, are equal in length, and the third pair is the shortest; each tarsus is terminated by three claws; the two superior ones are curved and slightly pectinated, and the inferior one is inflected near its base. The palpi resemble the legs in colour. The abdomen is oviform, hairy, glossy, convex above, and projects over the base of the cephalo-thorax; it is of a pale brown colour, with obscure spots of a deeper shade, the under part being rather the darkest; the sexual organs have a reddish brown hue, and their anterior margin is prominent and semicircular.

The colours of the sexes are similar. The male has the humeral joint of its palpi curved towards the cephalo-thorax, which has a narrow indentation immediately behind each lateral pair of eyes; the radial is larger than the cubital joint and projects a strong obtuse apophysis from its extremity, in front, towards the inner side; the digital joint is somewhat oval, with a large lobe on the outer side; it is convex and hairy externally, concave within, comprising the palpal organs, which are highly developed, complicated in structure, with a curved prominent process at their base, on the outer side, another, situated underneath, which has its extremity enlarged and depressed, and two long, contiguous, filiform, black spines, originating near their base, on the outer side, which pass obliquely downwards, and curving round their extremity, extend considerably beyond the termination of the digital joint: the colour of these organs is red-brown.

Early in October 1853 both sexes of *Neriëne herbigrada,* in a mature state, were detected among coarse herbage and moss growing in woods on the northern slope of Gallt y Rhyg. Like *Neriëne sulcata,* this species makes a near approximation to the spiders of the genus *Walckenaëra.*

XVIII.—*On the Mechanism of Aquatic Respiration and on the Structure of the Organs of Breathing in Invertebrate Animals.* By Thomas Williams, M.D. Lond., Licentiate of the Royal College of Physicians, formerly Demonstrator on Structural Anatomy at Guy's Hospital, and now of Swansea.

[With two Plate.]

[Continued from p. 137.]

The orbit of the blood-proper in the Annelid is conducted in obedience to the simplest hydraulic principles. The Annelid is vermiform in figure. A dorsal vessel carries the blood from the tail to the head, a ventral in the reverse direction. The intermediate currents invariably, in every species, bear *from* the latter *into* the former vessel. This fact is perfectly patent to the eye of every observer. The blood enters *into* the dorsal vessel from the viscera, *from* the ventral trunk *into* the viscera. In simplicity of mechanical principles nothing can exceed such an arrangement. The annulose 'circulation' observes two leading directions, longitudinal and transverse. The dorsal trunk is propulsive, the ventral distributive, the œsophageal ring connective. Let the circulatory system of the *articulated* animal be studied with reference to this comparative standard.

Myriapoda, Insecta, Arachnida.

These three classes are distinguished by *one type* of organization. The blood-system, the nervous, and the respiratory are constructed upon one essential plan. A law, true of one, cannot therefore suffer aberration in the other. The unity of nature's constructive principles are observed with rigid inviolability. The lowest Myriapod is removed from the highest Annelid only by a short distance: the former in the adult state has no chyl-aqueous fluid, the latter no tracheal system. Is it mechanically reasonable that the introduction of 'tracheæ' into the organism should involve a radical change of plan in the orbital direction of the blood-current? It must be so, if Mr. Newport's exposition of this subject be founded in truth. In the Annelid the eye follows with clearness and certainty the currents in all the lateral vessels attached to the dorsal trunk moving *into* or *in the direction* of the latter. In what Mr. Newport has called the *systemic arteries* in Myriapods and Arachnids, the blood moves in a contrary direction, from the dorsal vessel towards the viscera. Those very vessels which in the Annelid can be proved indubitably, by the eye, to be *veins*, are suddenly in the very next class reversed into *arteries*! Which is the more probable,—that her observers have perpetrated a paradox, or that nature has reversed her course? The subject deserves a more accurate examination.

All English and continental anatomists have implicitly followed Mr. Newport; where he is in error they are wrong, where he is truthful they are right. It is *his* exposition of this subject therefore that must be measured by the standard of actual nature. Disciples will obey the master-teacher.

Mr. Newport's researches on the "Circulation of the Blood" in the Myriapods, Insects, and Arachnids, constituted a remarkable æra in the anatomical history of the Invertebrate animals*. His researches are masterpieces of minute and difficult anatomy; they deserve, as they have received, the admiration of all scientific men. The age of authority is gone by. Truth must now be reverenced at her native shrine, and Mr. Newport must submit to the criticism of his peers. Mr. Newport's anatomy is exact, but his reasoning is unintelligibly contradictory. His researches relate exclusively to the *central parts* of the circulating system of the tracheary Articulata; he has not attempted to investigate the peripheric. This is a natural division of this subject. Let these heads be discussed separately.

Central Parts of the Circulatory System in the Myriapoda, Insecta, and Arachnida.

The researches of Baker, Carus, Wagner †, Lyonet ‡, Cuvier §, Treviranus ||, Latreille ¶, Straus-Durkheim **, Mr. Bowerbank ††, Tyrrel ‡‡, Müller §§, Hunter, Lord ||||, Newport ¶¶, in connexion with this subject, should be historically signalized; they deserve the reverence, but not the servile acceptance, of the scientific scholar; they involve a vast mass of laboriously acquired knowledge; they constitute the foundation whereon all future additions must rest.

The myriapodal 'circulation' exists in its least complex form in the *Iulidæ*. Of this family the *Spirostrepti* and *Spiroboli* represent the lowest genera. Mr. Newport has proved that the chambers of the heart *decrease* in number as the articulate scale is followed upwards from the lowest Myriapod to the highest Arachnid. This principle is *not* observed in the larva of all insects. In several aquatic species, the great venous abdominal currents may be followed most perfectly with the eye, and seen to enter the dorsal vessel *only* at its posterior extremity, where alone auricular orifices exist (Pl. IX. fig. 4, *b*). The dorsal vessel (*a*) of

* On the nervous and circulatory systems, and on the existence of a complete circulation of blood in vessels, in Myriapoda and Macrourous Arachnida, Phil. Trans. 1843. Also Art. *Insecta*, Cyclop. Anat. and Phys.; and various papers in the 'Linnæan Transactions,' by George Newport, Esq.

† Isis, 1832. ‡ Traité Anatomique de la Chénille, &c., 1760.

§ Leçons d'Anat. Comp.

|| Die Arachniden, 1812; and also his Vermischte Schriften Anatomischen und Physiologischen Inhalts. Göttingen, 1816 (Die Spinne), p. 5.

¶ Cours d'Entomologie, &c., Paris, 1831.

** Considérations générales sur l'Anat. Comp. des An. Art., 4to, Paris, 1828.

†† Entom. Mag. vol. i. April 1833.

‡‡ Proceedings of the Royal Society, 1835.

§§ Nova Acta Nat. xii. 2.

|||| Medical Gazette, 1838. ¶¶ *Op. cit.*

the larva of the Insect therefore bears a closer typal analogy to that of the Annelid than that which is presented by that of the lowest Myriapod. The dorsal vessel of certain transparent aquatic larvæ may be readily defined under the microscope; its pulsations and currents may be perfectly observed. The corpuscles floating in the blood mark with great clearness the direction of the current. It is certain that in some species the *systemic arteries* (fig. 1, *f*, & fig. 3, *n*, *n*.) (of Mr. Newport) do not exist. In those in which these vessels are detectable, the current which they convey tends *towards*, not *from*, the dorsal vessel. Repeated observations have convinced the author upon this point. They are venous, not arterial; they return the blood from the viscera into the dorsal vessel; these vessels are described everywhere, in all his writings, by Mr. Newport, as visceral *arteries*; his dissections have notwithstanding traced them into anastomosis with branches coming from the *supraspinal artery* (fig. 1, *c*, fig. 3, *c*, *e*, fig. 2, *b*). In *this* vessel the blood moves from the head in the direction of the tail; it follows therefore that the currents conveyed by the anastomosing branches must meet each other in the *same* vessel! action and reaction are equal and contrary! stagnation results! The *subspinal* venous trunk (fig. 3, *e*, *l*) discovered by Mr. Newport in Insects and Arachnids does not exist in the Myriapod. In the latter, therefore, the *primary* channels of the system of the blood do not exceed two in number, the dorsal and the ventral. This is the case in the Annelid; the ventral vessel of the Annelid *undulates* much *less* obviously than the dorsal. It receives *all* its blood from the dorsal by means of the œsophageal collar-branches: it distributes it chiefly to the integumentary structures. Trunks of secondary size proceed backwards, in some species from the heart, in others from the œsophageal vessels, expressly to supply the walls of the alimentary canal*. Now the *veins* which return this blood from the glandular parietes of the intestinal canal in the Annelid enter into the dorsal vessel precisely in the same manner as the systemic *arteries* are described by Mr. Newport to *proceed from* this vessel in the Myriapod, Insect, and the Arachnid. In classes so contiguous, why should the functions of the same vessels be reversed? Mr. Newport's views are drawn from anatomical structures; he has never *seen* the blood moving in these so-called systemic *arteries*; he ignores the argument of analogy drawn from the *living* circulation of the Annelid; he does not perceive the *mechanical* difficulty with which the blood would enter these vessels from the segmental heart, on the supposition of their arterial character. They arise from the latter at its extreme *posterior*

* See the Author's Report on the British Annelida in the Transactions of the British Association for 1851.

end (Pl. IX. fig. 3, *n*, *n*)—at that very point at which they should enter if they were veins.

A large wave of blood rushing forwards may be clearly *seen* in the dorsal vessel of larvæ (fig. 4, *b*, *a*): the chambered dorsal vessel contracts from behind forward; it observes the law of the Annelidan; the hindmost chamber contracts first, that next to it in advance next, and so on. The systolic movement does not occur throughout the whole length of the vessel at the same time, but in parts from behind forwards as the wave of blood travels. In two adjacent chambers the actions of systole and diastole are alternate.

There is in fact no functional difference whatever between the dorsal vessel of the Annelid and that of the articulated animal; they are distinguished only in structure. In the Myriapod, the tubular vessel of the Annelid is reinforced with propelling power at successive points = the chambered hearts. In the articulated animal this *extra* power in the central vessel is absolutely required. In the Annelid every vessel in the body is an elastic tube *tightly embracing* the fluid contents. The *channels* through which the blood moves in the Articulata do not closely grasp the contained fluid (fig. 2, *g*); they are indeed bounded by definitive membranes, but they are not elastic contractile structures fitted mechanically to favour the circulation of the fluids (Pl. X. fig. 10, *b*, *c*). This circumstance ought not to involve an alteration in the *type* of the circulation. But if the systemic arteries of Mr. Newport be really arteries, then the plan and principle of the circulatory systems of the Annelid and the Myriapod must be diametrically dissimilar. If they be arteries, the circuit of the fluids cannot be explained without involving physical contradictions. The author is however convinced that Mr. Newport has committed the mistake of imputing to vessels an arterial character, which observation and analogy prove to be venous.

The orbit of the blood-current in the Myriapod conforms in every particular with the Annelidan type. *All* vessels attached to the dorsal vessel *behind the œsophageal collar* (fig. 1, *b*) are *afferent* with respect to that trunk. *All* branches connected with the great ventral or supraspinal vessel posterior to the same limit are *efferent* with respect to this vessel. The currents in these latter branches are divisible into two orders—that first which supplies the viscera, that secondly which is distributed to the integuments: the current from the first, after having traversed the viscera *en route*, returns into the dorsal vessel under a *venous* character by means of the *systemic arteries* (sic) of Mr. Newport. That from the second is poured from various sources into the great splanchnic sinuses which enter the dorsal vessel at the auricular orifices.

In the *dorsal* vessel, from the extreme tail to the extreme head, the blood moves *forwards,* in the ventral backwards: in *all* branches whether integumentary or visceral, *from* the latter *into* the former. The dorsal vessel is afferent only with respect to those parts which are situated anteriorly to the œsophageal ring; the ventral is efferent only to the same parts—it is distributive to all others.

The preceding account of the course of the blood in the Myriapoda embraces conclusions suggested by careful study and numerous observations; it is recommended by its mechanical simplicity; it entangles the physiologist in no hydraulic contradictions.

That of the *Insect* (fig. 2) is regulated in exact conformity to the myriapodal type. The dorsal vessel (*a*) in the Insect exhibits signs of concentration; it is only the *abdominal* portion that is multiplied into chambers; through the thorax the vessel is continued in form of a simple tube. The auricular orifice of these chambers is furnished with a more perfect valvular apparatus. The same observations apply to the so-called *systemic arteries* of Insects as to those of Myriapoda. To the presence of these vessels in this class, however, no allusion is made by Mr. Newport*. If they exist in the Myriapod, they must also exist in the adult Insect.

The *supra-spinal* trunk (fig. 2, *b*) in Insects, as in Myriapods, is the great centre of the ventral circulation. It receives all its blood from the dorsal vessel by means of the anterior branches into which the latter divides; it supplies chiefly the external structures and the nervous chords. Either from the descending aortic branches or from the anterior part of the supraspinal artery, there proceed backwards along the ventral aspect of the viscera, one or more secondary trunks which correspond with those which in the Annelids are exclusively distributed over the parietes of the alimentary canal; in these, the direction of the blood corresponds with that in the great ventral artery; like the latter, they are afferent and distributive. All the blood, thus, by means of these trunks, entering the viscera from below, reaches again the dorsal vessel, conducted by the so-called "systemic arteries." In Insects the vessels connected with the abdominal circulation are more perfect, mechanically, as conduits, than those traversing the exterior structures of the body. This explains the difference of structure which exists between the systemic arteries (sic) and the *loose membranous channels* (fig. 2, *g*, *f*, *e*) opening into the auricles of the heart. The former belong to a distinct segment (the visceral) of the circulation, the latter to the integumentary or peri-

* See article *Insecta,* Cyclop. Anat. and Phys.

pheral. In the Insect, as in the Myriapod and the Annelid, the circulatory current acknowledges two main directions; in *all* dorsal trunks, from the extreme tail to the antennæ, the movement of the blood is *forwards*, in all ventral trunks it assumes an opposite course.

In all branches connecting more or less transversely these two systems of longitudinal trunks, the blood travels from below upwards, from the ventral in the direction of the dorsal trunks. On the supposition that the "systemic arteries" are distributive neither in Insects nor in Myriapods, is it possible to solve the mechanical problem of the circulation? As now explained, the principle of the system is intelligible and consistent. It is asserted with great confidence by the physiologist, that in Insects no distinction into venous and arterial blood can prevail. The ubiquity of the tracheæ renders such a distinction impossible.

Such are the doctrines now taught; they are not necessarily true; at present neither the extreme peripheric parts of the blood-system, nor those of the tracheæ are known. New questions, to be presently propounded, will prove that the material conditions of the processes of nutrition and respiration in the air-breathing Articulata are as yet by no means clearly defined. But let the central parts of the circulation in Arachnids be first defined.

To Mr. Newport is due the credit of first solving the problem of the 'circulation' in the Arachnid; but his solution is neither clear nor complete*. On his interpretation, conceding the merit of correctness to his descriptive anatomy, the circuit of the blood cannot be consistently described. Like that of the Myriapod and the Insect, the dorsal vessel (fig. 3, *p*, *a*) of the Arachnid extends from the tail to the head, along the dorsal median line. With its sides, along its entire course, there are connected two orders of branches; first, the pneumo- or brancho-cardiac canals (fig. 3, *k*, *k*, *k*), which return the blood from the pulmonary or branchial sacs (*g*); secondly, the systemic *arteries* (*n*, *n*) of Mr. Newport†. At its anterior extremity it breaks forth into a great number of branches destined for the supply of the appendages. To the dorsal vessel in the Arachnid Mr. Newport assigns an extraordinary duplicity of action. According

* See his papers in the Phil. Trans. Part ii. 1843.

† I am very desirous in this place to invite the attention of the student in comparative anatomy to the beautiful work now being published by M. Emile Blanchard; it is entitled 'L'Organisation du Règne Animal,' à Paris, chez Victor Masson et J. B. Baillière. The delineations which adorn this work are executed in the first style of French art. M. Blanchard implicitly follows the interpretation of the circulatory system of the Arachnids, rendered by Mr. Newport.

to him, the same straight vessel (*p, a*), and furnished too with valves opening in *one* direction, sends the blood in two diametrically opposed currents! forwards towards the head, and directly backwards towards the tail at the same moment*. He thus wantonly violates the unity of principle which presides over the distribution of the blood in the whole annulose and articulated series.

Directly contrary to the views of Mr. Newport, the blood in truth, in the *caudal artery* (fig. 3, *p*) of the Arachnid, moves *forwards*, not *backwards*. It follows therefore, that in the ventral trunk (*l*) of the tail of the Scorpion the direction of the current is backwards, not forwards as stated by Mr. Newport. The pneumo-cardiac channels (*k, k, k*) *enter* the auricles of the heart; the systemic arteries *arise* (Newport) from almost the same point in the walls of the chambers. The author has already argued in favour of the *venous* character of these vessels in Myriapods and Insects: if in the latter classes they be venous, they cannot be arterial in the Scorpion; they are the same vessels—they present the same relations—they are connected with the viscera in the same manner. They anastomose with the branches which proceed upwards from the supraspinal visceral arteries. Henceforth they will be called systemic *veins*.

At its cephalic extremity in the Scorpion, the dorsal vessel divides into three groups of secondary trunks (fig. 3, *b, c, d*),—those first which supply the brain, head and tentacles,—those secondly which proceed to the claws and legs,—and lastly those which form the great ventral longitudinal trunks of the body. In the Scorpion they consist of two orders, those first which Mr. Newport in this instance has called the visceral arteries (*b*), and secondly the *supraspinal artery* (*c*). If the visceral arteries exist as separate trunks in Arachnids, they must be present

* This is his language:—"Having traced the distribution of the arterial vessels from the anterior extremity of the heart, it remains now to follow those of the posterior, which *afford some curious peculiarities.* The last two chambers of the heart, which are situated in the seventh segment of the abdomen, are greatly reduced in size, and constitute the *origin* of the caudal artery (fig. 3, *p*, of the author's plate), and seem to be the means by which part of the current of the blood is *directed backwards to the tail.*" See page 292 of his paper on the Myriapods and Arachnids, in the Phil. Trans. 1843. There are eight valves to the heart. The anterior six act forwards. The two posterior act directly backwards (Newport)!—Is this probable, physiologically or mechanically? Does it not involve a hydraulic absurdity? Can the *same linear* tube, whose contractions *begin* behind and travel undulatorily *forwards*, drive the contained fluid simultaneously backwards and forwards? (!) *Why* should this reversal of the blood-current take place in the same homologous vessel in the Arachnid, and *not* in the Insect and the Myriapod? The mere addition of a *tail* to the Scorpion does not necessitate such a mechanical paradox.

under some form in the Myriapod and the Insect. They constitute a conspicuous class of distributive vessels in the Annelids. Mr. Newport does not suspect even their existence in the Myriapod and the Insect. He replaces them by his incomprehensible *systemic arteries*. In the pulmonary Arachnids a great *venous* abdominal trunk (fig. 3, *e, l*) is superadded to the system of the circulation. It conveys *forwards* the blood (according to Mr. Newport) from the caudal region. This again is undoubtedly an error. In this vessel in the Arachnid, as in the Insect, the course of the blood is *backwards*; it distributes it over the branchiæ, from which it is returned by the pneumo-cardiac channels to the heart again to repeat the same course.

The corresponding central parts of the *tracheary apparatus* require but few preparatory words:—

In the Myriapods the large tracheæ communicate externally with the spiracles. In the *Scolopendridæ, e. g.* the *Lithobius*, they exist on alternate rings to the number of eight or ten. The tracheæ proceed thence in longitudinal trunks to be distributed over every part of the body.

In Insects the *spiracles* are usually nine in number on each side; each spiracle consists of a horny ring of an oval form, within which is a valve formed of a series of converging fibres, and which opens perpendicularly on its long axis guarding the external entrance*. In the perfect Insect the spiracles of the abdomen are small, those of the larva large. In the latter, abdominal respiration is most active; in the former, the thoracic is predominant. In Insects as in Myriapods, the tracheæ, arising at the spiracles, are distributed over every part of the body (Plate X. fig. 8). The tracheæ of *all* larvæ are simply tubular, those of all volant perfect insects are dilated at various parts into *vesicles*.

In some tribes, as in most of the Hymenoptera, Lepidoptera, and Diptera, these sacs are present in almost every species and occupy a large portion of the interior of the body, more especially of the abdominal region. They exist only in the volant species of the Coleoptera. They are present in the winged Carabidæ, but not in the apterous. The tracheæ, in those species of Orthoptera which are merely saltatorial in habits, never dilate into vesicles. M. Emile Blanchard declares that the *substance* of the walls of these vesicles is channelled into plexiform passages for the blood. This is most certainly incorrect. These sacs have no reference to the respiratory process; they subserve only a mechanical use; without them the insect could not fly. They exist in the male of the common Glow-worm, but not in the female (Newport).

* Art. *Insecta*, Cyclop. Anat. and Phys.

The relation of the tracheæ to the blood-currents will be studied under the next head.

Peripheral extremes of the respiratory and circulatory systems in Myriapoda, Insecta, and Arachnida.

In their extreme distributions these two great systems will be most advantageously studied in connexion. There prevails between them an extensive parallelism; they are not, however, everywhere in coincidence. Though much has been accomplished by the ingenuity of minute anatomists during the last few years to dispel the difficulties of this subject, much still remains to be unravelled. Swammerdam, Malpighi, Lyonet, and Cuvier*, did really no more than discover the existence of the dorsal vessel. It was at this time that Cuvier first made the felicitous observation, "Le fluide nourricier, ne pouvant aller chercher l'air, c'est l'air qui vient le chercher pour se combiner avec lui." Cuvier believed the fluids in the Insect to be stagnant, except in the dorsal vessel, in which they only oscillated to and fro. In the year 1827 Carus *saw* the movement of the blood in the transparent larvæ of the *Ephemeridæ* and *Agrionidæ*†. Carus could not trace the currents to their remote courses. Wagner in 1832‡ confirmed the observations of Carus. Straus added his authority upon the same point. Mr. Bowerbank§ has published admirable observations on the circulation of the blood in the wings of *Chrysopa perla* and *Phlogophora meticulosa* in the order Lepidoptera. Mr. Bowerbank has in no instance, however, followed the blood beyond the larger nervures of the wings, in which he saw the current (accompanied always by a trachea) turning back at certain points. He nowhere states that these currents followed the tracheæ to their extreme ramifications. Mr. Newport corroborates these observations in his article "Insecta," in the Cyclopædia of Anatomy and Physiology. In the year 1848, M. E. Blanchard‖ published a celebrated essay, in which he first announced the ingenious experiments which led him to conclude that the blood *travelled* everywhere in the *sheaths* of the tracheæ:—"il est démontré que le fluide nourricier pénètre entre les deux membranes qui les constituent." M. Emile Blanchard does not attempt to show how the blood can describe a *circuit* in such a manner and in such a situa-

* Sur la Nutrition dans les Insectes, Mém. de la Société d'Hist. Nat. de Paris, 1797.

† Nova Acta Physica, vol. xv. 1834.

‡ Beobachtungen über den Kreislauf des Blutes, &c. bei den Insecten, Isis 1832.

§ Entomological Magazine, 1833.

‖ Annales des Sciences Nat., 3me série, Sur la Circulation dans les Insectes, &c.

tion. But his conclusions have by no means received the undivided assent of subsequent observers*. It is easy to prove that the coverings of the tracheæ are very unlike those implied in the inferences of M. Blanchard. This will be afterwards done.

Agassiz† declares that he has repeated the injections of M. Blanchard with confirmatory results. At this period M. Charles Bassi and M. Filippi‡ undertook especially to examine this question. They fed the *larvæ* of *Sphinx atropos* and *Bombyx mori* on indigo, cochineal and other coloured substances; they found on dissection that the tracheæ were everywhere coloured; they satisfied themselves that the colour was limited to the tunics of the aëriferous tubes; it never entered into the interior. Prof. Alessandrini§, varying the preceding observations, concludes from similar experiments that the coloured matter actually enters into the *interior* of the *tracheal tube*:—"Le Prof. Alessandrini crut remarquer que la matière colorée était contenue dans l'intérieur même des trachées, et que la coloration dépendait ainsi d'une véritable injection de vaisseaux trachéens." The famed observations of Mr. Bowerbank lend support to the views of the French and Italian observers just explained. He remarks, "the course of the blood is almost invariably in immediate connexion with that of the tracheæ." Mr. Newport, in his article "Insecta," teaches precisely the same doctrine. In a paper very recently‖ read before the Linnæan Society on the *Ichneumon atropos*, Mr. Newport states, "that the ramifications of the tracheæ which penetrate the structure of the alimentary canal and of every other organ, *become denuded of their external covering*, and then seem to form only two tissues, the *spiral* and the mucous; if indeed there be not also, as he has some reason to think, an extremely delicate serous or basement, closely adherent to and uniting the coils of the fibrous tissue on its external

* With reference to the remarkable relation which, according to M. Blanchard, subsists between the tracheæ and the blood, it is important that his views should be clearly apprehended. He says again,—"Mais n'est-ce pas plus encore sous le rapport de la *nutrition* que ces tubes respiratoires, dont nous connaissons la nature actuellement, doivent arrêter notre attention. En portant de l'air dans leur intérieur ils portent le sang dans leur périphérie. Ces trachées divisées et ramifiées à l'infini dans la profondeur de l'économie conduisent ainsi le fluide nourricier à tous les organes, à tous les muscles au moment même, où il vient de subir le contact de l'air. C'est le sang nouvellement artérialisé, le sang propre à vivifier, à nourrir tous les organes."—*Op. cit.* p. 380.

† Annal. des Sc. Nat. 1851, and Proceedings of the American Association for the Advancement of Science, Cambridge, U.S., &c.

‡ Ann. des Sc. Nat. 1851.

§ At the Scientific Congress held at Geneva, Sept. 1851.

‖ See Annals and Magazine of Nat. Hist. for July 1853.

surface. The *ultimate divisions of the tracheæ are always distributed separately and do not anastomose*, ending, as noticed by Mr. Bowerbank, in *extremely minute, filiform, blind extremities, and this Mr. Newport finds to be their condition in all structures*, in the nervous and integumentary, in the glandular and muscular*". M. Blanchard† has very recently proved the existence in the Arachnids of a *true capillary network*? at the extremes of the circulation. "This network," he remarks, "which has not yet been pointed out in the Articulata, exists under the integuments and between the various layers of the muscles, in the connective tissue; it consists of *distinctly circumscribed canals lined with a thin epithelium*. Thence the blood is received by the venous canals‡." Thus is presented in bibliographic but faithful outline the sum of existing knowledge on the distribution of the air-tubes and the blood-channels in the air-breathing Articulata: who can say that it exhibits a consistent history? The physiologist rises from the scene confounded by its manifold contradictions. The assertions of one observer are opposed and outweighed by those of another. Mr. Newport, the most recent and laborious investigator, leaves the subject utterly unintelligible; his observations cannot be verified in nature.

The author does not, for one moment, pretend to affirm that his researches (now first published) have as yet destroyed the possibility of all controversy upon *every part* of this subject. He does, however, believe that he has *finally* settled *one* part,—that which relates to the extreme distribution of the tracheæ. He has not definitively established, by actual demonstration, the manner in which the blood is related to the *extreme* tracheæ. On this subject he will state at present only what he has clearly and confidently observed.

It should first be affirmed as an absolute principle, from which there can be no departure, that a tracheal tube is an *air*-tube in *every part* of its course. It is not, as supposed by Agassiz and M. Léon Dufour§, an air-tube in its proximal moiety, and a

* I have given in the text at length the views of Mr. Newport, as reported in the abstract published in the 'Annals'; I have indicated the points in controversy by italics. They express the results of Mr. Newport's last and very recent observations. It will be afterwards seen by the text, that the conclusions at which I have arrived, from numerous and scrupulous examinations of the very same points, differ in a remarkable degree from those just communicated by Mr. Newport to the Linnæan Society.

† Comptes Rendus, June 20, 1853, p. 1079. See also the beautiful figures in his work 'Sur l'Organisation du Règne Animal.'

‡ See translated abstract in the Annals and Mag. of Nat. Hist. for Sept. 1853.

§ "Elles se divisent, comme dans les Insectes en général, en *trachées-artères* ou grand *canaux aérifères*, et en *trachées nutritives*, qui naisent des premières, et vont épanouir leurs subtiles ramifications dans tous les tissus."—Ann. des Sc. Nat. tome xv. no. 2. p. 76, 1852.

blood or circulatory conduit in its distal; the microscope everywhere proves such a view to be an unmitigated error. It is quite another and more rational supposition to maintain that the *passages* which bear the tracheæ may probably serve also to convey the nutritive fluids. Even this opinion requires the evidence of new demonstration. The author will now proceed to consider the results of his own recent investigation, distributed under the following heads:—1. The structure of the tracheæ. 2. Their distribution; (*a.*) in the adult and larval internal structures; (*b.*) in the branchiæ, in connexion with the question of insect aquatic respiration. 3. The anatomical relation in which the tracheæ stand to the nutritive fluids. 4. The mechanism of respiration in air-breathing Articulata.

Structure of the Tracheæ.

The air-tubes in Myriapods, Insects, and Arachnids, admit of division into two distinctly different parts: 1. the *spiral trachea*, and 2. its capillary continuation, the *membranous*. The former is a continuously tapering tube, branching arborescently, the branches never re-entering. It is always and everywhere furnished with an elastic spiral by which its bore is maintained in an open state. It is composed, as stated originally by Sprengel, of three anatomical elements (Pl. X. fig. 13); the outermost (*a*) consists of a dense membrane which swells under the agency of acetic acid, and *separates* from the spiral on which it normally rests and to which it forms *a close investment*. When raised by acetic acid it retains the impress of the spiral. This would not be the case if the membrane did not naturally *closely embrace the spiral*. And if it did closely embrace the spiral, it required no further persuasive to satisfy the physiologist that between it and the spiral there can by possibility travel no current of blood. This simple experiment is quite enough to effect the demolition of M. Blanchard's theory. All structures *external* to this membrane belong to the blood-channels (fig. 10, *b*, *c*) and not to the trachea. From the coverings of the latter they are quite dissimilar in anatomical structure; they are really the *loose* delicate membranes which constitute the walls-proper of the blood-channels. They are attached to the tracheæ only by loose adhesions. If now, while the tube is under the reagency of acetic acid, the eye search for the internal lining membrane (fig. 13, *c*), which lies on a plane to the inside of the spiral, it will appear with as perfect clearness as the external. It swells and separates from the *spiral* like the external. It is impossible to *prove* the existence of much difference of structure between this and the external membrane; it is more delicate and less refractive. The spiral lies in the space between these two membranes. On close inspection it seems as if a membrane distinct from the two former united together tubularly the coils of the spiral, and that the spiral itself consisted of a *hollow tube* formed out of cells arranged spirally in the substance of this membrane. In a short time the *fibre* of the spiral, after immersion in acetic acid or turpentine, loses its dark, highly refractive *solid* character. It appears distinctly as though its substance were permeated by the fluid and that air was displaced. In this state the spiral looks like a pellucid diaphanous coil wound around the axis formed by the internal membrane. This description applies to every *spiral* trachea in the body. But there is a limit, different in different structures, at which the *spiral ceases*. It is at this point that the second division of these tubes or *membranous tracheæ* begins. It is not the *external covering*, as stated by Mr. Newport, which ceases, but the *spiral* (Pl. IX. fig. 5, C, *e*). This fact admits of various and unquestionable proofs. The spiral grows less and less visible until it graduates insensibly into a *continuous* tube (*f*, *g*). It still however retains the peculiar optical character of a *trachea*. Its edges are faint *reddish*, from the iridescent decomposition of the light. This appearance was observed by MM. Alessandrini, Filippi and Bassi. The latter of these observers believed that the tint was due to the colour of the hollow cylinder of coloured blood which embraced the air-tube, corroborative of the views of M. Blanchard. It should rarely be ascribed first to the high refractive index of the air contained in the tube, and next to the density of the external fibrous membrane. It is a character by which a membranous air-tube, though of capillary diameter, can be distinguished with certainty from a blood-channel or a capillary blood-vessel. The direct continuity of the *bore*, as well as of the walls of this membranous capillary air-tube, with the larger and spiral trachea, can be proved in several modes beyond the possibility of dispute. By pressure, skilfully managed, while the specimen is under the microscope, air may be forced from the 'spiral' into the membranous tube; but the continuity of the walls of the latter with those of the former is so clear and convincing under the microscope, that no other evidence is required to prove that the capillary membranous tube is to the 'spiral' as a capillary is to an artery. The diameter of the 'spiral' trachea constantly decreases as it divides; that of the membranous observes throughout its entire course, whether it multiply into a network (Pl. X. fig. 9, *d*, *e*), or wavy brushes (fig. 12, *c*, *d*, *f*), or into the muriform plexus which exists in the substance of muscles (Pl. X. fig. 15), a uniformity which can compare only with that of true blood-capillaries of the vertebrated animal.

A tracheal tube, in many instances at the point of penetrating into the substance of a solid organ provided with a membranous investment, will *appear*, from the close and tubular manner in which it is embraced by this membranous investment, to throw off, as supposed by Mr. Newport, its external coat at the point of entrance. Acetic acid however proves this appearance to be false. The tube still preserves its three constituent elements *after* entering the substance of the organ, whatever it be, and until it assumes the capillary or membranous character.

It is important to observe, because it reconciles the accurate observations of Mr. Bowerbank with those of the author, that on the *wings* (fig. 10, *f*), especially on the scaly intervals between the nervures, the *spiral* tracheæ, as correctly stated by Mr. Bowerbank, do *not* for the most part degenerate into the *membranous* tracheæ. In these situations the *spiral* continues to the extreme termination of the tube (fig. 11, *b*). There is something anatomically characteristic in the walls of the membranous tracheæ. They denote a difference between those 'parietes' through which a *gas* has to pass, and those (of the vessels) which *fluids* transude. The smallest trachea differs from the largest only in the absence of the spiral, just as the largest artery differs from the capillary only in the presence of a thick elastic coat. The tracheæ terminate differently, and form different plexuses, in different organs, according to the varying mechanical arrangements of the ultimate parts of the latter.

The conclusion must be emphatically reiterated, that however, wherever, and in whatever structure the tracheæ may peripherically terminate, they are *air*-tubes throughout all changes to their final extremes.

Distribution and Subdivision of the Tracheæ.

The primary, secondary and tertiary tubes divide and subdivide arborescently, the branches never reuniting (fig. 14). In the *spiral* tracheæ no plexiform union of the branches ever, anywhere, occurs; so far the observations of Mr. Bowerbank and Mr. Newport are exact to nature. It is because these distinguished observers could not succeed in tracing the air-tubes beyond this limit, and because they drew a general inference intended to be applied to *all* structures, from the distribution and termination observed by the tracheæ in the wings, that they were both seduced into the error of supposing first these points to be the distributive *ultimata* of the tubes, and secondly, that the tracheæ nowhere inosculate. As already stated, this is true only of the scaly intervals which separate the nervures of the wings—*of no other structures*. In nearly *every other* structure in the body of the Insect the air-tubes divide and subdivide in the same profuse retiform manner as the blood-capillaries of the vertebrated animal. In the *muscles* the ultimate membranous tracheæ divide and unite plexiformly (figs. 14, 15). The meshes are large and oblong (fig. 15). Some tubes run parallel with the ultimate muscle-fibre; others cross the latter at right angles, connecting the former. In the glands the capillary tubes *enclose* the space occupied by the gland-cells (fig. 9): they unquestionably *reticulate,* and in their ultimate form preserve a remarkable uniformity of diameter. In many parts of the mucous membranes they observe a peculiar *wavy* method of distribution (fig. 12). They elaborately reticulate in the loose structure beneath the integuments. It is by no means improbable that M. E. Blanchard has mistaken the plexus formed by the *tracheæ* in the integuments of the Arachnids for a *rete* consisting of true blood-vessels. In the nervous tissue they follow two modes of subdivision. The brain substance is actually *penetrated* by the plexiform capillary tubes. The nerves are accompanied by long undulating filaments.

In some of the voluntary muscles the tracheæ are profusely numerous. The larger spiral branches enter the sheaths of the muscle=fascicles at right angles (fig. 14); the *membranous* tracheæ into which in the substance of the muscle they subdivide, coincide generally in direction with the fibres of the muscles (fig. 15). In other muscles the primary entering tracheæ are few in number. As a rule it seems at present probable, that the volume of air (oxygen) which by means of the tracheæ enters into the substance of a *solid* organ in the tracheary Articulata is *directly* as the *vital importance* of that organ. The reticulation of the tracheæ is most dense and profuse in the glandular and nervous structures. The large spiral air-tubes which travel along the axes of the spacious blood-channels, detach from their sides here and there *minute wavy* branches (fig. 10, *j, b*) which *float in the fluid,* and which appear to be expressly intended to aërate the *fluids*. These floating air-tubes are everywhere seen where the blood-stream comes into contact with the main trachea. The main tracheæ are simply convective. It will afterwards appear that the function of these *floating tracheæ* is distinct from that of those plexiform extremes of the system which penetrate and traverse the substance of the solid organs. *These aërate immediately the solids, those the fluids.*

The distribution and subdivision of the tracheæ in the branchiæ of the aquatic larvæ of Insects involve the consideration of the mechanism and significance of aquatic respiration as it occurs in the young of the air-breathing Articulata. Is it *real* aquatic breathing, or is it only apparently so?

In the larvæ and pupæ of gnats, the branchiæ exist in the form of slender hair-like organs arranged in tufts. Each filament is penetrated by a single trachea and an advancing and returning current of blood. In the *Agrionidæ* (fig. 5, *a*) they assume the character of lancet-shaped processes attached to the sides of the abdomen at the points of the future spiracles. Examined carefully as transparent objects, the tracheæ of these branchiæ divide and subdivide much more elaborately than is commonly supposed (fig. 5, B, *b*). It is only the *larger* tracheæ that are accompanied by a current of blood (fig. 9, *i*, *b*, fig. 12, *e*). The latter is much *less* profusely subdivided than the former. This fact seems incontestably to prove that the tracheæ, *not* the blood-channels, extract the air from the surrounding water. In the anal branchiæ of the *Libellulidæ*, M. Léon Dufour exhibits the tracheæ (fig. 7) as terminating in *bulged* extremities (fig. 7, B, *a*). The author will only state that he has never, in the course of his numerous researches, in any instance met with this mode of termination. In the filiform branchiæ of the larva of gnats each trachea tapers to the finest extreme.

In *Pteronarcys regalis* Mr. Newport describes the branchial filaments as consisting "each of a simple, unarticulated, uniform structure, slightly tapering and closed at its extremity, and in the interior of which there is an extremely minute tracheal vessel* terminating in delicate cæca." In no one of his writings is it evident that Mr. Newport is aware to what an extreme degree of *capillary* subdivision the tracheæ are carried in the *flat branchiæ* (fig. 6, B, *c*), if not in the filiform, of the larvæ of Insects. In those of the *Agrionidæ*, cut off and examined separately under the microscope, they cannot be followed by the highest powers of the microscope. The blood-current turns back at the larger branches: it does not ramify in network streams. It is obviously not designed to fulfil the office of breathing: this function falls upon the tracheæ. This conclusion is opposed to the views of Mr. Newport. "The blood-corpuscles of the whole body circulate through the branchiæ for the purposes of respiration. The current of the blood is always in the vicinity of the tracheæ, absorbing oxygen by endosmose and giving out carbonic acid. *This takes place in every form of branchiæ* †." The author is fully satisfied that this is an erroneous interpretation of the respiratory process as it occurs in the branchiæ of Insects. The ramifications of the tracheæ in these organs are far more elaborate than Mr. Newport and other observers have ever yet supposed. They render the inference irresistible that the branchial respiration of the Insect is really atmospheric in type. The air does not, as in fish-breathing, enter immediately into the blood.

In the vessels of Insects in every phase of life, there seems to

* Linnæan Transactions, 1851.

† *Op. cit.* p. 432.

be some structural peculiarity which *unfits* them for the interchange of *gases*. There resides on the contrary in the walls of the tracheæ a marvellous endosmotic property, which enables them to give passage in any direction to *gaseous* elements with extraordinary facility. There occurs then in reality no example of true branchial breathing in the larvæ of Insects. It is only the extracting of air from the water instead of directly from the atmosphere*. The aquatic life of the Insect therefore is only apparent, not real. The *principle* of the respiratory process is the same whether in or out of the water, whether in the larva or imago state, whether with internal tracheæ or external branchiæ. There is no example of *real* aquatic breathing.

What light then do these anatomical minutiæ reflect on the question which involves the *mechanism of nutrition and respiration in the tracheary Articulata*? That is the question now to be considered. It is surpassingly interesting. If the conclusions which the author is about to present should prove to be exact, the physiologist will have approached nearer to a solution of the ultimate problem of respiration. He will see this function under a new phase—under strikingly novel conditions.

In all the transparent structures of Insects, such as the wings, antennæ, branchiæ, &c., every observer may prove for himself that the blood-currents travel in the same passages as the tracheæ (fig. 10, *b*, *k*, *c*). On closer scutiny it will be seen that a channel, such as the nervure of the wings, bearing in its centre a large tracheal tube (*k*), exhibits on *one* side of this tube a current going in one direction (*b*); on the other, another bearing in an opposite course (*c*). These are afferent and efferent, arterial and venous blood-streams. They are bounded by separate walls. The afferent current is circumscribed by its own proper coats, the efferent by *its* own; and the trachea is placed intermediately, having parietes quite distinct from, though contiguous to, those of the blood-channels. This coincidence between the tracheæ and the blood-currents can be traced in the wings nowhere beyond the limits of the nervures into the scaly spaces which they circumscribe. The returning of the corpuscles at a certain point renders this fact quite unquestionable. Beyond this limit *only the fluid elements*, not the corpuscles of the blood, extend. In this extra-vascular region it is *cyclosis*, not circulation, which

* M. Léon Dufour contends for the same principle: "Le dernier terme de la composition organique serait donc ici, comme dans les branchies des Poissons, une trame *vasculaire*, en ne donnant à ce dernier mot que sa valeur rigoureusement étymologique, c'est-à-dire anatomique. Seulement dans les Poissons c'est du *sang*, et dans les Insectes de l'*air*, qui est renfermé dans les vaisseaux de cette trame." Ann. des Sc. Nat. 1852, tom. xvii.

governs the movements of the nutritive fluid. If the same passages served everywhere for the blood and for the tracheæ, and if their parallelism was unexceptional and universal, wherever the tracheæ could be seen, there also should be observed the corpuscles of the blood. This is the case only in the primary and secondary, *never* in the capillary tracheæ (fig. 11, *b*). The blood-corpuscles (fig. 10, *g*) in the Myriapod, Insect, and Arachnid exceed by several times in diameter that of the extreme capillary membranous tracheæ. It is perfectly marvellous to what inconceivable minuteness the *air*-current is reduced in travelling along these tubes. It affords a captivating example of the illimitable divisibleness of matter.

If *everywhere* the blood and the air travelled together, branched together, *capillated* in concert,—if *everywhere* a *double* blood-current to *one* air-tube could meet the eye, the inference could not be resisted, that the sole, entire and exclusive design of the tracheal apparatus of the Insect consisted in aërating *the fluids*.

Since, however, the blood *returns far before* the tracheæ reach their remote *penetralia*;—since the comitance between the blood and the air is broken abruptly at a limit *proximal* to the extremes of the organism, *it is certain* that the tracheal system in the Insect fulfils some other function—answers some other end—than that merely of aërating the *fluids*. What can be the meaning of those incomparable *pneumatic plexuses*—veritable *retia mirabilia*—which embrace immediately the *very ultimate elements* of the *solid* organs of the body;—those microscopic air-tubes, which carry oxygen *in its gaseous form*, unfluidified by any intervening liquid, to the very seats of the fixed solids which constitute the fabric of the organism? There is an immeasurable difference between oxygen dissolved and oxygen free. In the former case, all the *forces* liberated during the moment of condensation from the elastic to the fluid form are expended upon the *blood*, and that, too, remote from the scene at which that blood is to be utilized; in the latter case, free, gaseous and uncombined, it is delivered immediately at the spot where the oxygen is to be employed; it electrizes by direct combination the last sedentary elements of the organism; by such an arrangement those forces attendant on chemical action vivify undissipated the very ultimate components of the body at the very moment of their disengagement. This then is the real difference between an insect and every other living animal. This is the unequalled mechanism which renders the insect a *multum in parvo*, the unsolved riddle of creation. In *all* other animals the quickening action of oxygen is first *exclusively* exhausted upon the *fluids*; in the insect, the fluids are only partially influenced as the vitalizing element travels forwards to operate *immediately*, in its *un*exhausted form, on the final elements which conspire to maintain the nutrition of the living body.

The intense electrical and chemical effects developed by the immediate presence of oxygen, *in the gaseous form*, at the actual scene of *all* the nutritive operations of the body, fluid and solid, give to the insect its vivid and brilliant life, its matchless nervous activity, its extreme muscularity, its *voluntary* power to augment the animal heat; such contrivance, subtle and unexampled, reconciles the paradox of a being microscopic in corporeal dimensions and remarkable for the relative minuteness of the *bulk* of its blood, sustaining a frame graceful in its littleness, yet capable of prodigious mechanical results.

EXPLANATION OF PLATES IX. AND X.

Plate IX.

Fig. 1. Plan of the central parts of the circulatory system of the Myriapod, constructed in part from Mr. Newport's figures and in part from the author's dissections: *a, d,* the dorsal vessel; the arrows mark the direction of the blood; *b*, the œsophageal collar; *c* & *e*, supraspinal artery; *f*, the systemic arteries (sic) of Mr. Newport.

Fig. 2. Plan of the central parts of the circulatory system of the Insect: *a,* dorsal vessel. The anterior or thoracic half is a smooth tube, the abdominal chambered by valves; *b*, the supraspinal artery, having on either side venous currents (*c*), as shown by the arrows; *d,* branches, distributive, from the supraspinal artery; *e,* large, loose-walled venous channels entering the capacious abdominal sinuses *g, g*; *f,* the membranous channels which pour their blood into the dorsal vessel at the auricular orifices. The blood in the dorsal vessel moves forwards, that in the supraspinal artery moves backwards.

Fig. 3. *a, p,* Dorsal artery; *p,* its caudal continuation; *d,* its cephalic; *b,* visceral artery, sending distributive branches (*i*) into the viscera, the blood of which is returned into the dorsal artery by *n, n,* the systemic arteries of Mr. Newport; *c,* the supraspinal artery, conveying blood to the nervous and integumentary structures; *e,* subspinal vein; *f,* branches going to the pneumo-branchiæ (*g*); *h,* origin of the pneumo-cardiac channels (*k, k, k*); *l,* continuation of the subspinal vein into the tail; *m,* branches communicating with the dorsal artery (*p*).

Fig. 4. Glassy, jelly-like aquatic larva of an Insect, common in the pools about Swansea: *a* (*c*), kidney-shaped tracheal vesicles, without any ramifying tubes; *b,* dorsal vessel; *d,* arrows denoting the returning into the dorsal vessel at the posterior auricles (*b*).

Fig. 5. Aquatic larva of *Sialis Lutarius*: *a,* branchial appendages; B, one of the branchiæ enlarged; *b,* tracheæ; *c,* cell-tissue.

Fig. 6. Aquatic larva of one of the *Libellulidæ*: *a,* branchial appendages; B, the same further enlarged; *b,* trachea; *c,* secondary arborescent branches; C, extreme end of one of the tracheal branches traced under a high power to its membranous capillary termination *f, g*.

PLATE X.

Fig. 7. Rectal branchiæ of *Æshna grandis,* after M. Léon Dufour: C, *a,* orifices in the rectum of the branchial folds (A); *a,* dilated extremities of the tracheæ.

Fig. 8. Head, tail, digestive system (*d*), tracheal (*h*) and branchial (*g*) systems, hepatic vessel (*e*), of *Agrion Puella,* after M. Dufour.

Fig. 9. A small piece from the parietes of the intestine of the Cockroach, showing the extreme distribution of the trachea (*a*). The blood-current accompanies the tube only as far as *i*. The trachea then describes a true network (*e, c, d*) of *membranous* tubes. In the meshes the glandular cells (*f, g*) are placed. A clear space intervenes between the trachea and glandular cells in which the nutritive fluids, without the corpuscles, may probably move.

Fig. 10. A small piece of the wing of the Cricket drawn under a high power: *a,* a large trachea in the centre of the nervure or channel, surrounded by two opposed currents of blood (*b, c*); *i,* larger branches; *d, e, f,* small terminal tracheæ, entering alone, *without* coincident, blood-currents into the *scaly* interval; *j,* long, slender, wavy tracheæ floating in the fluid; *g,* blood-corpuscles, travelling in the channel *b*.

Fig. 11. One of the tracheæ from the scaly intervals between the nervures of the wing of the Cricket, showing the mode in which it terminates (*b*) between the scales *d*.

Fig. 12. A minute portion of walls of the stomach of the Cockroach, showing the wavy manner (*c, f*) in which the *membranous* capillary tracheæ are distributed around and between the ultimate glandular elements; at *e*, the current of the blood, as traced through the blood-corpuscles, turns back: *a,* large spiral tracheæ.

Fig. 13. A small portion of a spiral trachea, exhibiting the coats under the action of acetic acid: *a,* outer coat raised, indented like the spiral (*b*); *c,* the internal or mucous coat.

Fig. 14. A piece of voluntary muscle, representing the manner in which the tracheæ enter the substance of the muscle.

Fig. 15. One of the above tracheæ traced *into* the substance of the muscle; *a, b, c,* network of ultimate membranous tracheæ as they are distributed between the ultimate muscle-fibres—the latter being omitted.

[To be continued.]

XIX.—*Description of a new genus and species of Seal* (Heliophoca Atlantica) *from Madeira.* By Dr. J. E. Gray, F.R.S., V.P.Z.S. &c.

Some months ago Mr. MacAndrew most kindly procured for me the skin of a Seal from the island of Madeira. A careful examination of it convinced me that it was a new species, most allied to *Phoca barbata* of the North Sea, but yet quite distinct from it. Mr. MacAndrew after considerable trouble at length obtained for me another skin of an older animal with its skull, which proves that it is not only a new species, but presents a new combination of characters such as I believe entitle it to be